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Annual Scientific Report to Air Force Office of
Scientific Research

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October, 1982 - September, 1983

Statistical Aspects of Reliability, Maintainability,
and Availability

Reliability Center
Department of Statistics
The Florida State University
Tallahassee, Florida 32306

Myles Hollander and Frank Proschan
Co-Principal Investigators

October, 1983

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A. Summary.

1. During the past year, under Grant AFOSR 82-K-0007, a total of 16 research reports were issued (Section B), 22 papers were published in scientific journals and books (Section C), 32 papers are in press or accepted for publication (Section D), and 5 books are in preparation (Section E).

2. A list of topics under study during the past year is given in Section F; the list is by no means complete.

3. Reliability Center activities during the past year included:

- (a) consulting for Eglin Air Force Base under an annual contract,
- (b) interaction with visitors to initiate and carry on reliability research,
- (c) continuation into the 12th year of the weekly Reliability Club Colloquia Series, and
- (d) responding to requests for advice from the AFOSR (Section G).

B. Reports Prepared During the Past Year.

1. Kumar Joag-Dev. "A Characterization of Independence in a Family of Distributions Exhibiting Certain Positive or Negative Dependence". AFOSR 82-152. September, 1982.

2. Myles Hollander, Dong-Ho Park, and Frank Proschan. "Testing Whether New is Better Than Used of a Specified Age". AFOSR 82-153. January, 1983.

3. Roger L. Berger and Frank Proschan. "Monotonicity in Selection Problems: A Unified Approach". AFOSR 82-154. September, 1982.

4. James Lynch and Frank Proschan. "Dispersive Ordering Results". AFOSR 83-155. February, 1983.

5. Roger Berger and Frank Proschan. "Applications of a Unified Theory of Monotonicity in Selection Problems". AFOSR 83-156. March, 1983.

6. S. W. Dharmadhikari and Kumar Joag-Dev. "The Gauss-Tchebyshev Inequality for Unimodal Distributions". AFOSR 83-157. June, 1983.

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Chief, Technical Information Division~~

7. Wai Chan, Frank Proschan, and Jayaram Sethuraman. "Convex-ordering among Functions, with Applications to Reliability and Mathematical Statistics". AFOSR 83-158. July, 1983.

8. Jee Soo Kim and Frank Proschan. "Total Positivity: A Review". AFOSR 83-159. July, 1983.

9. Frank Guess, Myles Hollander, and Frank Proschan. "Testing Whether Mean Residual Life Changes Trend". AFOSR 83-160. August, 1983.

10. Philip J. Boland and Frank Proschan. "The Impact of Reliability Theory on Some Branches of Mathematics and Statistics". AFOSR 83-161. August, 1983.

11. Robert A. Fontenot and Frank Proschan. "Some Imperfect Maintenance Models". AFOSR 83-162. August, 1983.

12. Catherine D'Abadie and Frank Proschan. "Stochastic Versions of Rearrangement Inequalities". AFOSR 83-163. September, 1983.

13. Myles Hollander, Dong Ho Park and Frank Proschan. "Testing Whether New is Better Than Used of a Specified Age, with Randomly Censored Data". AFOSR 83-164. September, 1983.

14. Emad El-Newehi and Frank Proschan. "Component Relevancy in Multi-state Systems". AFOSR 83-165. September, 1983.

15. Philip J. Boland and Frank Proschan. "Computing the Reliability of k out of n Systems". AFOSR 83-166. September, 1983.

16. Catherine D'Abadie and Frank Proschan. "Stochastic Rearrangement Inequalities". AFOSR 83-167. September, 1983.

C. Papers Published in Journals or Books During Past Year.

1. Boland, P.J. and Proschan, F. "Optimum Replacement of a System Subject to Shocks", Operations Research 31, 697-704, 1983.

2. Boland, P.J. and Proschan, F. "Periodic Replacement With Increasing Minimal Repair Costs at Failure", Operations Research 30, 1183-1189, 1982.

3. Boland, P. and Proschan, F. "The reliability of k-out-of-n systems", Ann. Probability 11, 760-764, 1983.

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4. Bolviken, E. and Joag-Dev, K. "Monotonicity of the Probability of a Rectangular Region Under a Multivariate Normal Distribution", Scandinavian Journal of Statistics 9, 171-174, 1982.

5. Brown, M. and Proschan, F. "Imperfect Maintenance", Survival Analysis 2, 179-188, 1983. Edited by John Crowley and Richard A. Johnson.

6. Campbell, G. and Hollander, M. "Prediction Interval With a Dirichlet-Process Prior Distribution", The Canadian Journal of Statistics 10, 103-111, 1982.

7. Chen, Y.Y., Hollander, M. and Langberg, N.A. "Testing Whether New is Better Than Used with Randomly Censored Data", The Annals of Statistics 11, 267-274, 1983.

8. Chen, Y.Y., Hollander, M. and Langberg, N.A. "Tests for Monotone Mean Residual Life, Using Randomly Censored Data", Biometrics 39, 119-127, 1983.

9. El-Newehi, E., Proschan, F. and Sethuraman, J. "A Multivariate New Better Than Used Class Derived from a Shock Model", Operations Research 31, 177-183, 1983.

10. Fahmy, S., Proschan, F., Pereira, C.A.B. and Shaked, M. "The Influence of the Sample on the Posterior Distribution", Communications in Statistics A 11, 1757-1768, 1982.

11. Hannum, R. and Hollander, M. "Robustness of Ferguson's Bayes Estimator of a Distribution Function", The Annals of Statistics 11, 632-639, 1983.

12. Hollander, M. "Hollander Bivariate Symmetry Test", Encyclopedia of Statistical Sciences 3, 650-652, 1983. Edited by Kotz and Johnson, John Wiley & Sons, Inc.

13. Hollander, M. "Hollander Extreme Test", Encyclopedia of Statistical Sciences 3, 653-656, 1983. Edited by Kotz and Johnson, John Wiley & Sons, Inc.

14. Hollander, M. "Hollander Parallelism Test", Encyclopedia of Statistical Sciences 3, 656-659, 1983. Edited by Kotz and Johnson, John Wiley & Sons, Inc.

15. Hollander, M. "Hollander-Proschan New-Better-Than-Used Test", Encyclopedia of Statistical Sciences 3, 659-662, 1983. Edited by Kotz and Johnson, John Wiley & Sons, Inc.

16. Joag-Dev, K., Perlman, M.D. and Pitt, L.D. "Association of Normal Random Variables and Slepian's Inequality", The Annals of Probability 11, 451-455, 1983.

17. Joag-Dev, K. and Proschan, F. "Negative Association of Random Variables, with Applications", The Annals of Statistics 11, 286-295, 1983.

18. Joe, H. and Proschan, F. "Tests for Properties of Residual Life", Commun.-Statist. Theor. Meth. 12, 1121-1134, 1983.

19. Joe, H. and Proschan, F. "Tests for Properties of the Percentile Residual Life Function", Commun.-Statist. Theor. Meth. 12, 1087-1119, 1983.

20. Lacayo, H., Pereira, C., Proschan, F. and Sarndal, C.E. "Optimal Sample Depends on Optimality Criterion", Scandinavian Journal of Statistics 9, 47-48, 1982.

21. Langberg, N.A., Johnson, R.B. and Bradley, R.A. "Short Communication: Stochastic Models for the Random Location of Individuals in a Habitat", Stochastic Processes and Their Applications 12, 327-333, 1982.

22. Langberg, N., Leon, R.V., Lynch, J. and Proschan, F. "Extreme Points of the Class of Discrete Decreasing Failure Rate Average Life Distributions", TIMS/Studies in the Management Sciences 19, 297-304, 1982.

D. Papers Accepted or Scheduled for Publication.

1. Barlow, R.E. and Proschan, F. "Distributions with Monotone Failure Rate". To appear in Handbook of Reliability by I. Ushakov.

2. Berger, R.L. and Proschan, F. "Applications of a Unified Theory of Monotonicity in Selection Problems". Inequalities, ed. by Y. L. Tong, 1984.

3. Berger, R.L. and Proschan, F. "Monotonicity in Selection Problems: A Unified Approach". Ann. Statist. 1984.

4. Borges, W., Proschan, F. and Rodrigues, J. "A Simple Test for New Better Than Used in Expectation". To appear in Commun. Statist.-Theory and Methods.

5. Brown, M. "Further Monotonicity Properties for Specialized Renewal Processes". To appear in Ann. Probability.

6. Brown, M. "Approximating DFR Distributions by Exponential Distributions, with Applications to First Passage Times". To appear in Ann. Probability.

7. Brown, M. "On the Choice of Variance for the Log Rank Test". To appear in Biometrika.

8. Brown, M. and Proschan, F. "Imperfect Repair". To appear in J. Appl. Prob..
9. Campbell, G. and Hollander, M. "Prediction Intervals with the Dirichlet Process Prior". To appear in the Canadian Journal of Statistics 11 (1983).
10. Chan, W., Proschan, F. and Sethuraman, J. "Convex-Ordering Among Functions, with Applications to Reliability and Mathematical Statistics". Inequalities, ed. by Y. L. Tong, 1984.
11. D'Abadie, C.A. and Proschan, F. "Stochastic Versions of Rearrangement Inequalities, with Applications to Statistics". Inequalities, ed. by Y. L. Tong, 1984.
12. El-Newehi, E. and Proschan, F. "Degradable Systems: A Survey of Multistate System Theory". Commun-Stat..
13. Fontenot, R.A. and Proschan, F. "Transformations Which Preserve Convexity". International J. Math..
14. Hollander, M. "Tests for Dependence". To appear in Ency. Stat. Sci., ed. by Johnson and Kotz. John Wiley & Sons.
15. Hollander, M. "The Bivariate Symmetry Test". To appear in Ency. Stat. Sci., ed. by Johnson and Kotz. John Wiley & Sons.
16. Hollander, M. "A nonparametric test for parallelism. To appear in Ency. Stat. Sci., ed. by Johnson and Kotz. John Wiley & Sons.
17. Hollander, M. and Korward, R.M. "Nonparametric Bayesian Estimation of the Horizontal Distance Between Two Populations". To appear in the Proc. of the János Bolyai Colloquium on Nonparametric Statistical Inference (1983). North Holland Publishing Company.
18. Hollander, M., Park, D.H. and Proschan, F. "Testing Whether F is More NBU Than is G". Reliability and Safety.
19. Hollander, M. and Proschan, F. "Nonparametric Concepts and Methods in Reliability". To appear in Handbook of Statistics 4, ed. by P.R. Krishnaiah.
20. Joag-Dev, K. "A Characterization of Independence Via Uncorrelatedness Under Certain Dependence Structures". Ann. Probability.
21. Joag-Dev, K. "Measures of Dependence". Handbook of Statistics, Vol. 4, ed. by P.R. Krishnaiah and P.K. Sen.
22. Joag-Dev, K. and Dharmadhikari, S.W. "Mean, Median, Mode III". Statistica Neerlandica.

23. Joag-Dev, K. and Dharmadhikari, S.W. "Recurrence of Symmetric Random Walks". J. of Management and Math. Sc..

24. Joag-Dev, K. and Dharmadhikari, S.W. "Slepian Regions". Proc. Symp. Probability Inequalities, Lincoln, NE.

25. Joag-Dev, K. and Dharmadhikari, S.W. "Unimodality of Symmetrized Unimodal Laws and Related Results". To appear in Lehmann Festschrift.

26. Joag-Dev, K., Shepp, L. and Vitale, R.A. "Remarks and Open Problems in the Area of the FKG Inequality". Proc. Symp. Probability Inequalities, Lincoln, NE.

27. Joe, H. and Proschan, F. "Comparison of Two Life Distributions on the Basis of Their Percentile Residual Life Functions". Canad. J. Statist..

28. Joe, H. and Proschan, F. "Percentile Residual Life Functions". To appear in Operations Research (Special Reliability Issue, 1983).

29. Kim, J.S. and Proschan, F. "Total Positivity". Handbook of Statistics, ed. by P.R. Krishnaiah.

30. Kitchin, J., Langberg, N.A. and Proschan, F. "A New Method for Estimating Life Distributions from Incomplete Data". To appear in Statistics and Decisions.

31. Lynch, J., Mimmack, G. and Proschan, F. "Dispersive Ordering Results". J. Appl. Prob..

32. Proschan, F. and Shaked, M. "Random Averaging of Vector Elements". SIAM J. Appl. Math..

E. Books in Process.

1. Barlow, R.E., Proschan, F. and Singpurwalla, N.D. Case Studies in Reliability and Life Testing.

2. Barlow, R.E., Proschan, F. and Singpurwalla, N.D. Inference and Data Analysis in Reliability and Life Testing.

3. Barlow, R.E., El-Newehi, E. and Proschan, F. Statistical Theory of Reliability and Life Testing: Probability Models, Second Edition.

4. Hollander, M. and Proschan, F. Statistics for People Who Count.

5. Hollander, M. and Proschan, F. Uses of Statistics - Explained in Words.

F. Research Topics Studied During Past Year.

A partial list of topics treated may give some idea of the scope of the research performed under the Grant:

Optimum maintenance policies.

Degradable system (multistate system) theory.

Relationship between coherent structures and power functions.

Testing whether mean residual life changes trend.

Nonparametric estimation of a discrete survival function when observations are censored.

Measuring the effect of increased censorship on an estimate of a life distribution.

Partial ordering of life distributions based on their dispersion.

Generalization of total positivity.

A generalization of covariance to more than two random variables.

Negative association of random variables, with applications.

Imperfect maintenance.

Tests for monotone mean residual life using randomly censored data.

Continuous versions of majorization and Schur functions.

Imperfect repair.

Optimum maintenance policies when repair is random.

k-out-of-n systems.

Percentile residual life functions.

Comparison of distributions on the basis of percentile residual life functions.

Characterization of independence.

Symmetric random walks.

The FKG Inequality.

Measures of dependence.

Slepian regions.

Piecewise exponential estimators of life distributions using censored data.

Testing for degree of NBU property.

Types of component relevancy in multistate systems.

G. Reliability Center Activities During Past Year.

1. Research Visitors.

Visitors to the Reliability Center have contributed greatly to the research output under the Grant. Money has been rebudgeted under the Grant to fund the travel expenses of established and emerging reliability theorists. The cost-effectiveness of this approach has been established: a small amount spent on travel reimbursement is as effective in yielding useful publishable reliability research as is a large amount spent on salaries for additional investigators.

Actual visitors to the Reliability Center include Robert Fontenot, Philip Boland, Kumar Joag-Dev, Emad El-Newehi, Charles Yates (Eglin A.F. Base). In addition, a large number of coauthors (visitors on earlier occasions) remained in contact with the Reliability Center by mail and telephone. These contacts through actual visits, mail, and telephone help explain the high productivity of our Reliability Center.

2. Consulting.

Charles Yates, Eglin Air Force Base, visited the Reliability Center to seek consulting aid. As a result, a contract has been established with the Consulting Center of our Department to provide consulting services to Eglin Base by Duane Meeter, Director of the Consulting Center, and a research aide for one year. The problems generally involve finding optimum combinations of design variables to maximize system performance; the computer plays a significant role in the optimization search.

3. Colloquia Series.

The weekly colloquia of the Reliability Center continue as in the past. The Series is entering its 12th year. The topics are in reliability and supporting mathematics and statistics. The popularity of the colloquia remains high among faculty, visitors and students.

4. Advice to AFOSR. During the past year, the Reliability Center responded to requests for advice from the AFOSR.